

Source-Receptor Modeling of Ambient $PM_{2.5}$ in the Upper Ohio River Valley Region



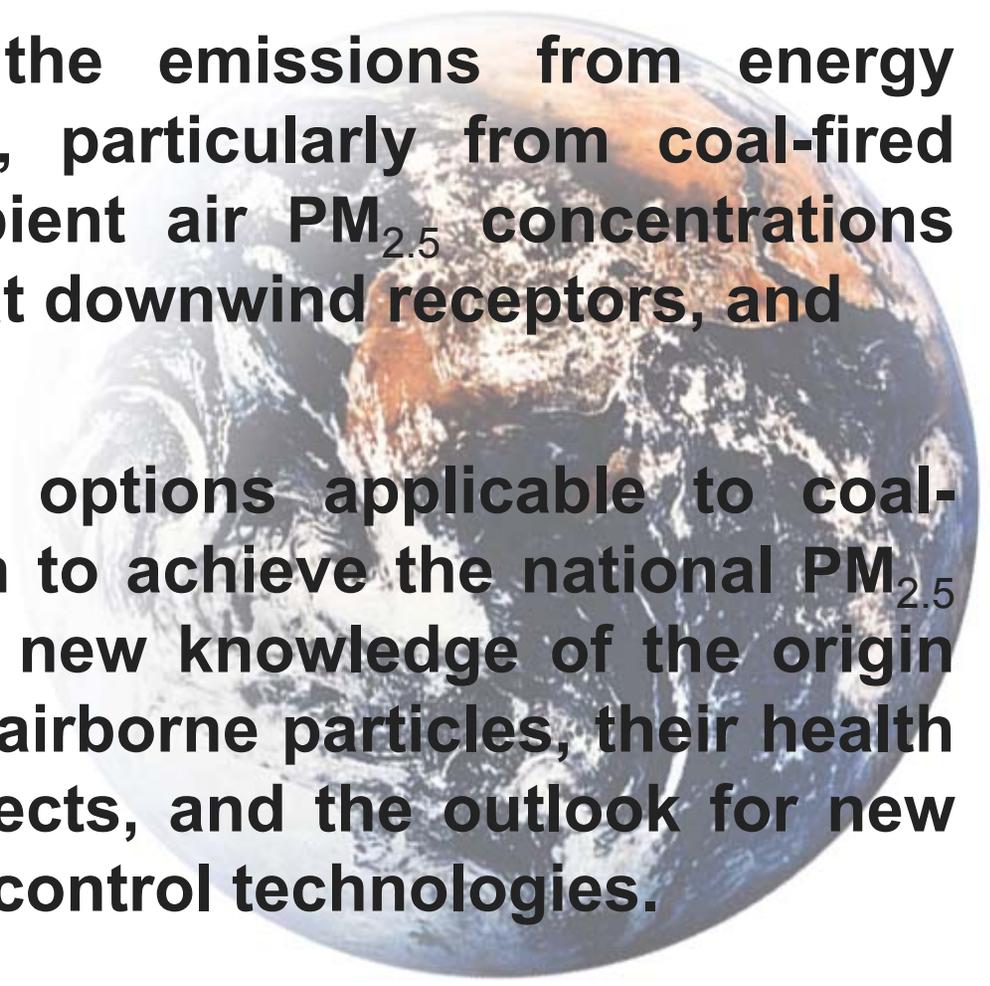
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Air Quality Research Goals

- Quantitatively relate the emissions from energy production (and use), particularly from coal-fired power plants, to ambient air PM_{2.5} concentrations and human exposure at downwind receptors, and
- Develop management options applicable to coal-fired power generation to achieve the national PM_{2.5} standards, integrating new knowledge of the origin and characteristics of airborne particles, their health and environmental effects, and the outlook for new or improved emission control technologies.



Experimental Approach

- **Collect Samples**
 - **Continuous and Filter Based Samplers for Analysis of Gas Phase and Fine Particle Weight and Composition**
- **Fine Particle Characterization**
 - **Methods include PIXE, IC, and EC/OC**

Experimental Approach

- **Apply Models to Data**
 - **Examine variations in Fine PM weight and composition as a function of regional meteorology**
 - **Determine source composition profiles and speculate on sources**

Regional Sampling Sites



UORVP Sites

- ① - Lawrenceville
- ② - Holbrook
- - Satellites

SCAMP Sites

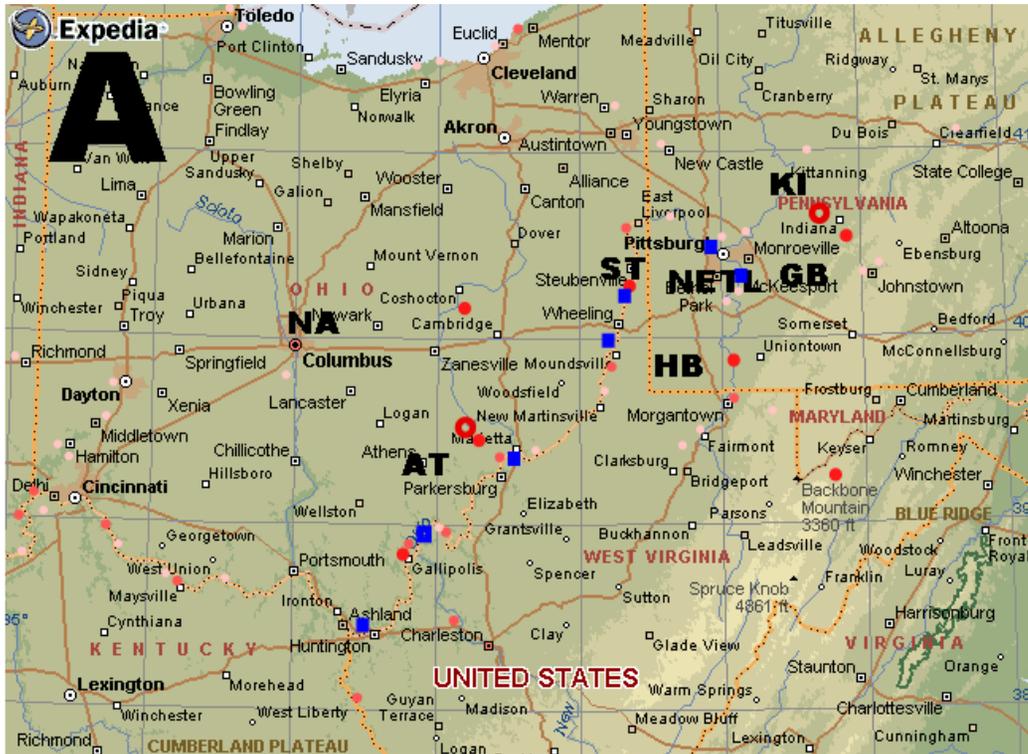
- ① - Primary
- - Satellites

☆ - NETL In-House Site

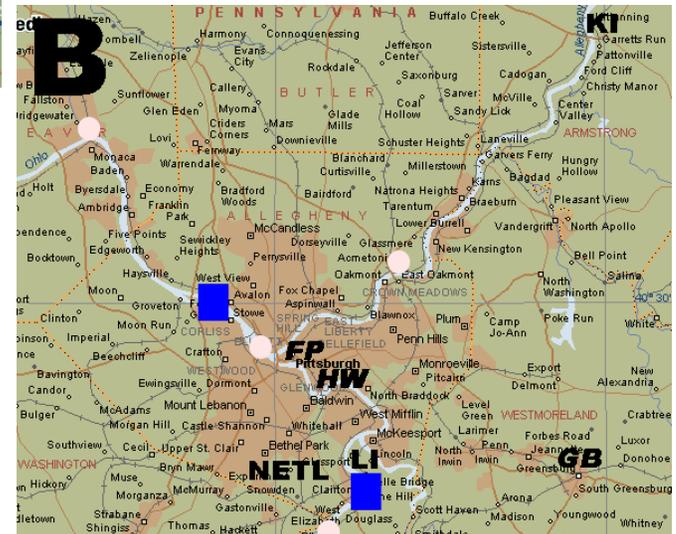
△ - CMU "Supersite"

Coal-fired
Power Plants

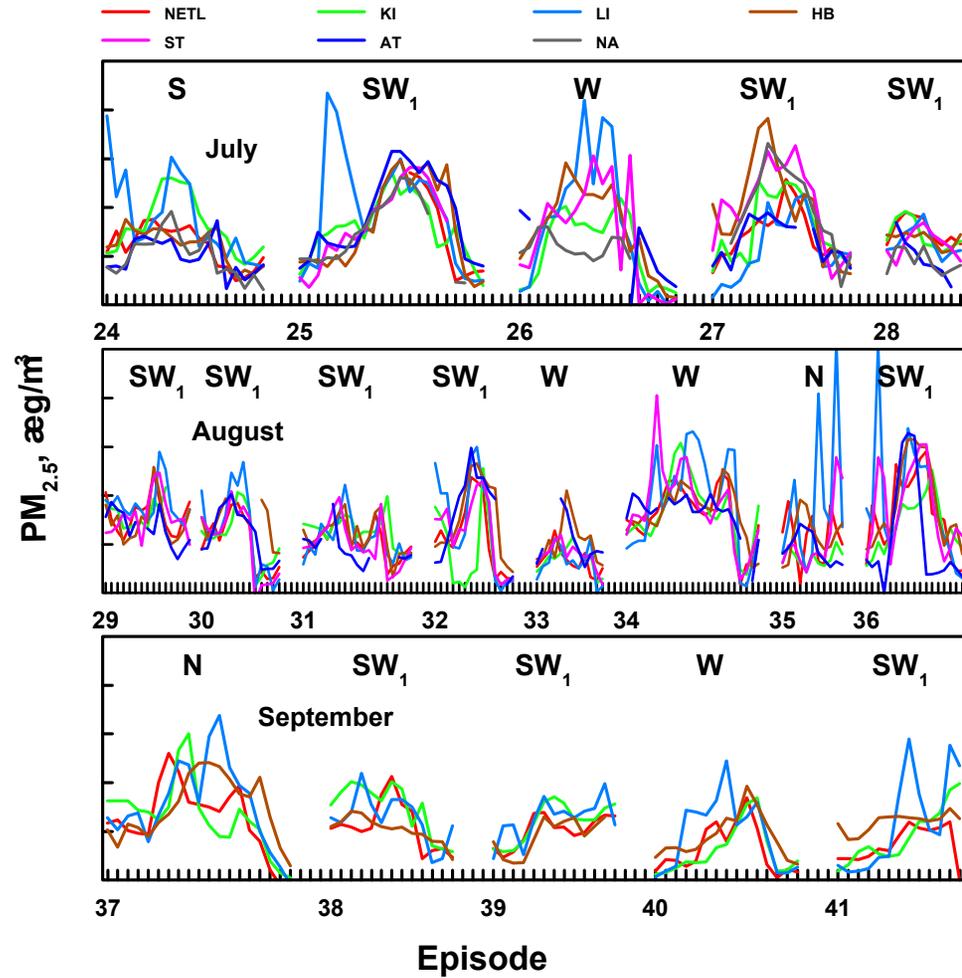
Regional Power Plants



Source Legend



Regional Episodes Summer 2000



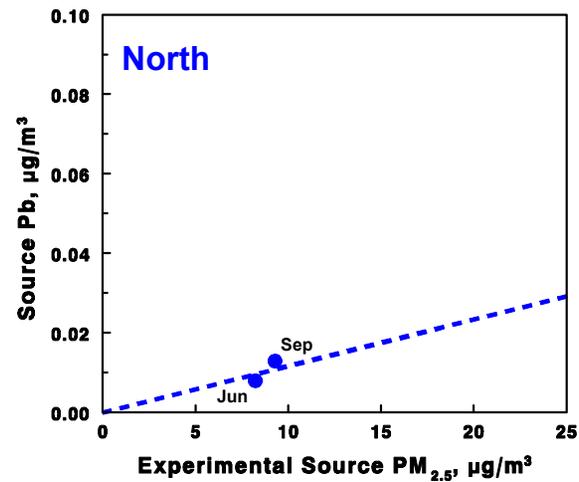
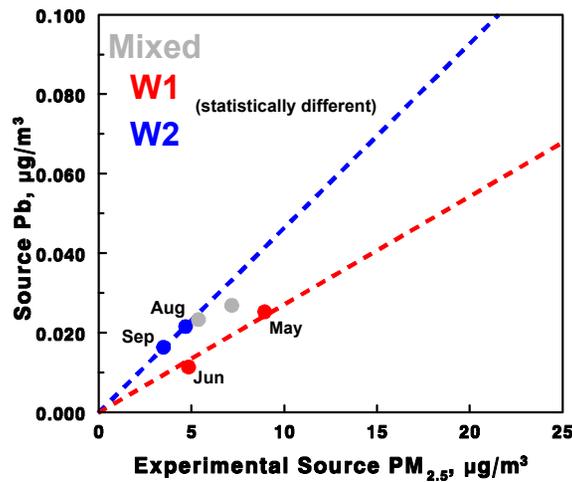
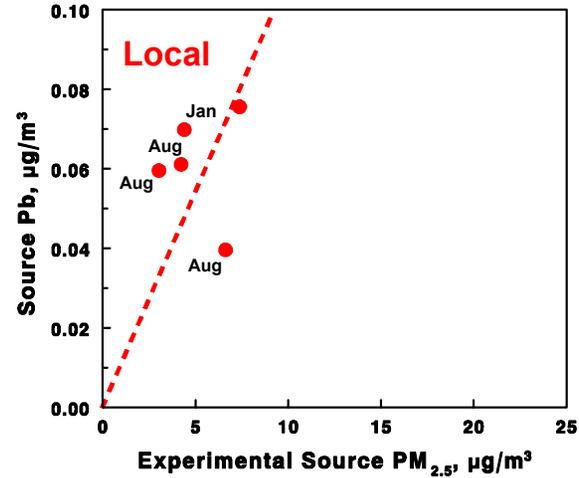
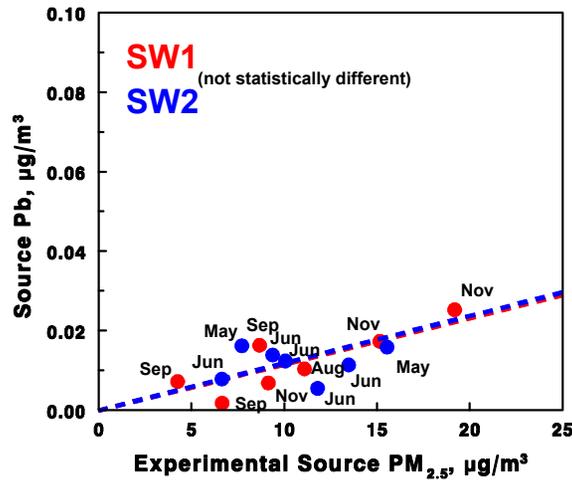
Qualitative Results

- **Relationships observed between levels of Fine PM and predominant geographic weather direction**
 - **High PM_{2.5} episodes associated with transport during passage of frontal systems from Ohio River Valley to west and southwest of sampling sites**
 - **High PM_{2.5} episodes associated with transitions from locally high pressure to lower pressure**
 - **Concentrations of PM_{2.5} during high pressure periods were generally low throughout the study region**
 - **After episodes as pressure increased, concentrations of PM_{2.5} often sharply decreased at all sites**

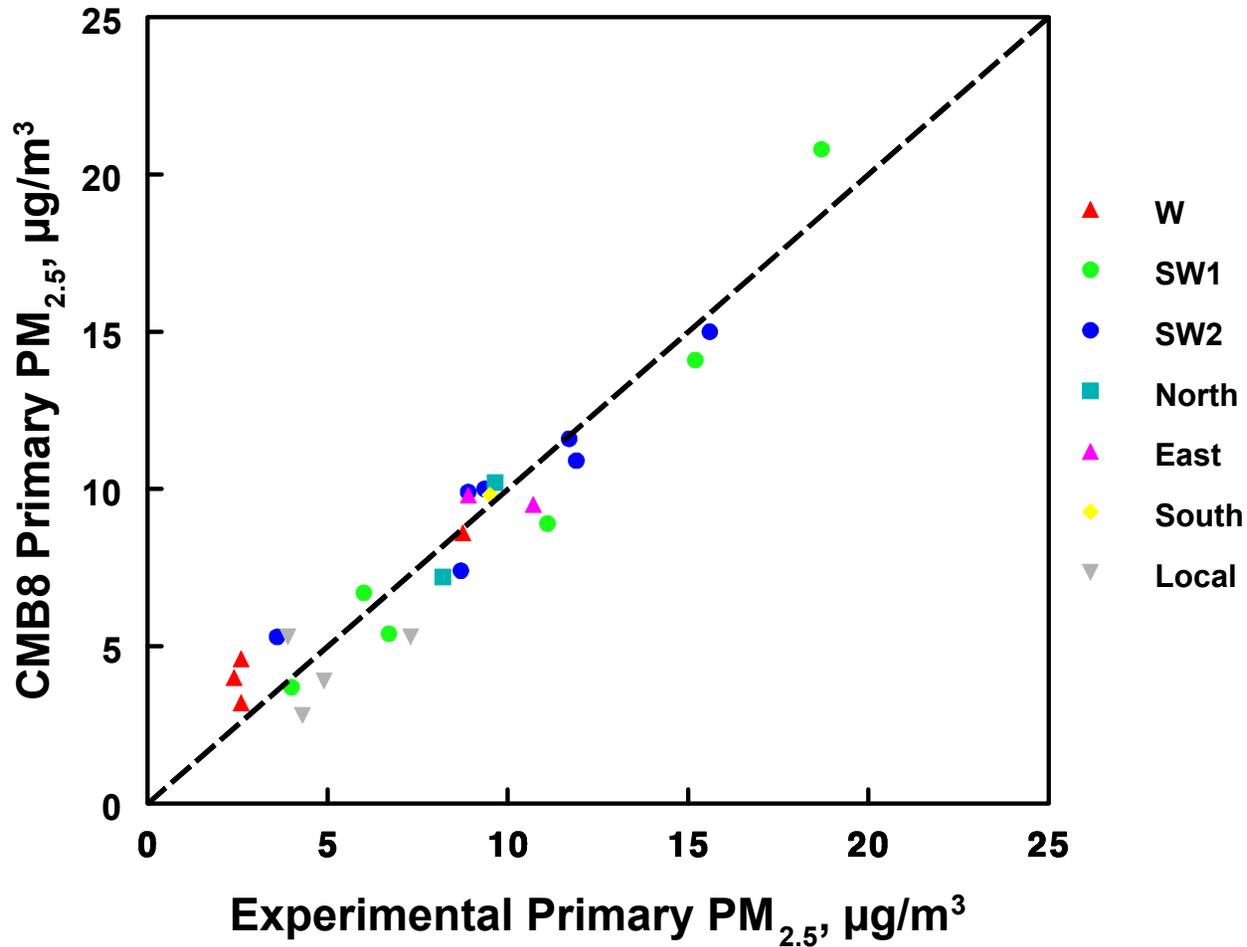
Quantitative Modeling

- **Apply CMB8 model to test hypothesis that directional source profiles can be developed to determine directional apportionment of $PM_{2.5}$ transported into the region**
 - Develop directional source composition profiles for $PM_{2.5}$
 - Use combination of inorganic PIXE and EC / OC analysis data from NETL $PM_{2.5}$ samples, August 2000
 - NOAA Hysplit meteorological back-trajectory model used to determine predominant geographic origin of 24 hour sampled air masses
 - For each characteristic source direction, individual background crustal corrected elemental inorganic or EC component mass was regressed against primary $PM_{2.5}$ mass
 - Directional Source Profiles developed from regression slopes

Lead Data, CMB8 Directional Profile Development



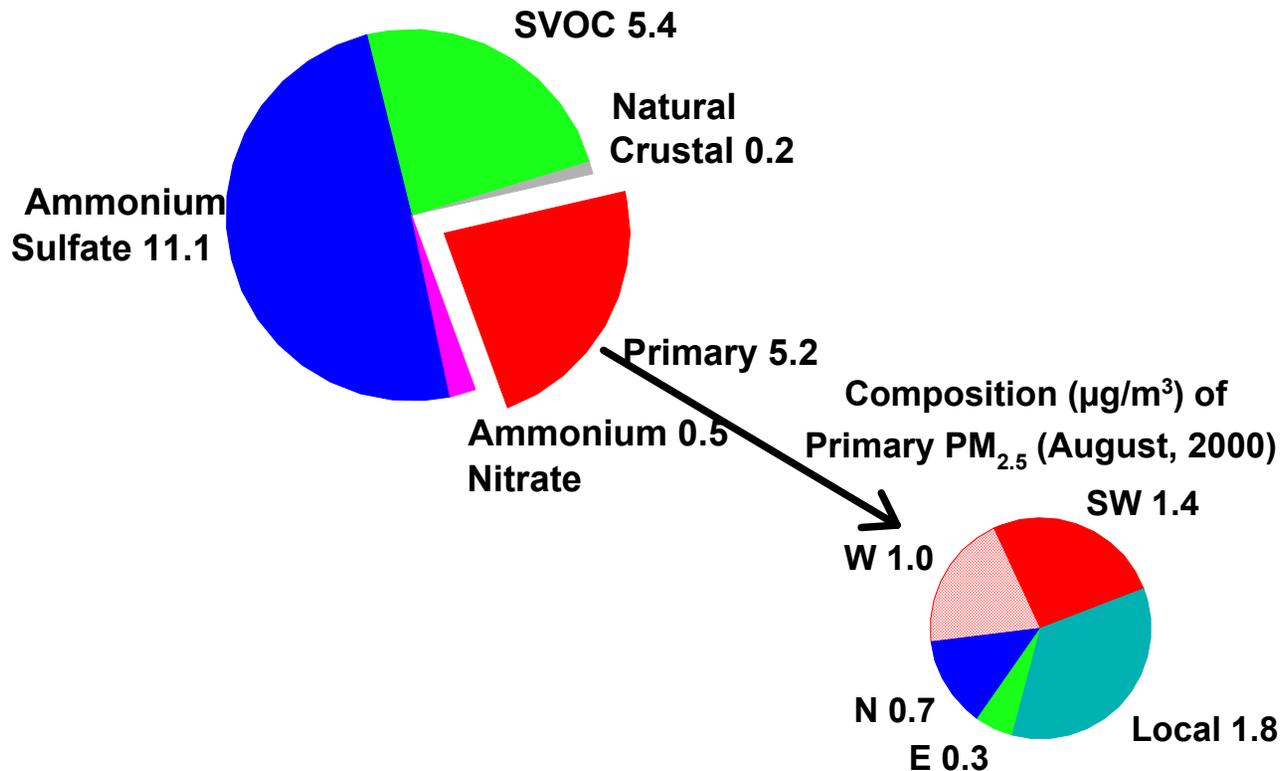
CMB8 versus Hysplit Observations



$Y = 0.9422x + 0.4305, R^2 = 0.9122$ unconstrained correlation

PM_{2.5} Directional Compositions for Primary Particles (EC and PIXE)

Composition ($\mu\text{g}/\text{m}^3$) of
PM_{2.5} (August, 2000)



Results

- **The Primary PM consists of Local and Transported origins**
- **Greatest sources Primary PM are from Local, South West, and West transport directions**
- **Most of the Secondary PM is Ammonium Sulfate from distant sources**

Examine Regional vs. Local Sources

- **Unmix 2.3 model**
- **EPA – DOE Summer (July) 2001 Intensive Sampling Period**
- **CMU Supersite (5 samples / day) and NETL Sampling Site (4 samples / day)**
- **VOM, SVOM, NVOM, and Ammonium Sulfate used in model**

PC-BOSS Samples

- **Gas phase volatile organic material (VOM)**
- **Filter retained nonvolatile organic material (NVOM)**
- **Semi-volatile particulate organic material captured on the CIG after the denuder (SVOM)**
- **Fine particulate ammonium sulfate**
- **Fine particulate elemental carbon (EC)**

Continuous Gas Data

- **Gas phase NO_x (A marker of primary emissions)**
- **Gas phase NO_2 (A marker of secondary formation processes)**
- **Gas phase O_3 (A marker of secondary formation processes)**

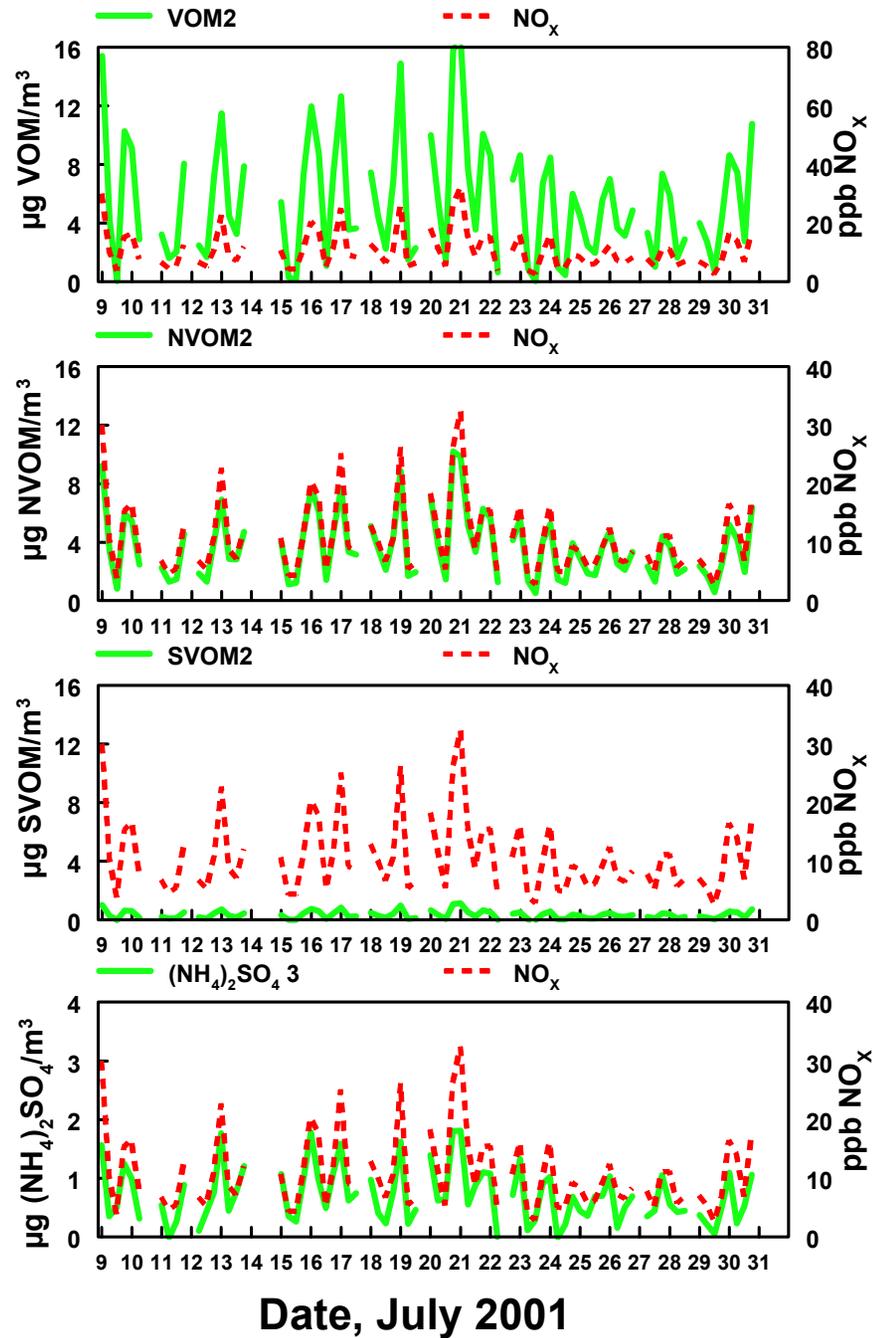
UNMIX Source Solution Profiles for PM_{2.5} at the CMU site

Tracer/Species	Source 1 (Mobile diesel)	Source 2 (Local Sec.)	Source 2 (Transport Sec.)	Source 3 (Mobile gas)
EC/PM _{2.5}	0.421	-0.076	0.005	0.023
VOM/PM _{2.5}	4.261	1.509	0.321	4.799
NVOM/PM _{2.5}	0.861	-0.170	0.143	0.787
SVOM/PM _{2.5}	0.843	0.285	0.068	0.103
NO _x /PM _{2.5}	1.273	0.588	-0.029	6.725
NO ₂ /PM _{2.5}	0.362	1.567	0.101	3.949
(NH ₄) ₂ SO ₄ /PM _{2.5}	-0.055	0.797	0.774	-0.140
Average PM_{2.5}	1.09	1.28	15.43	2.44

UNMIX Source Solution Profiles for PM_{2.5} at the NETL Site

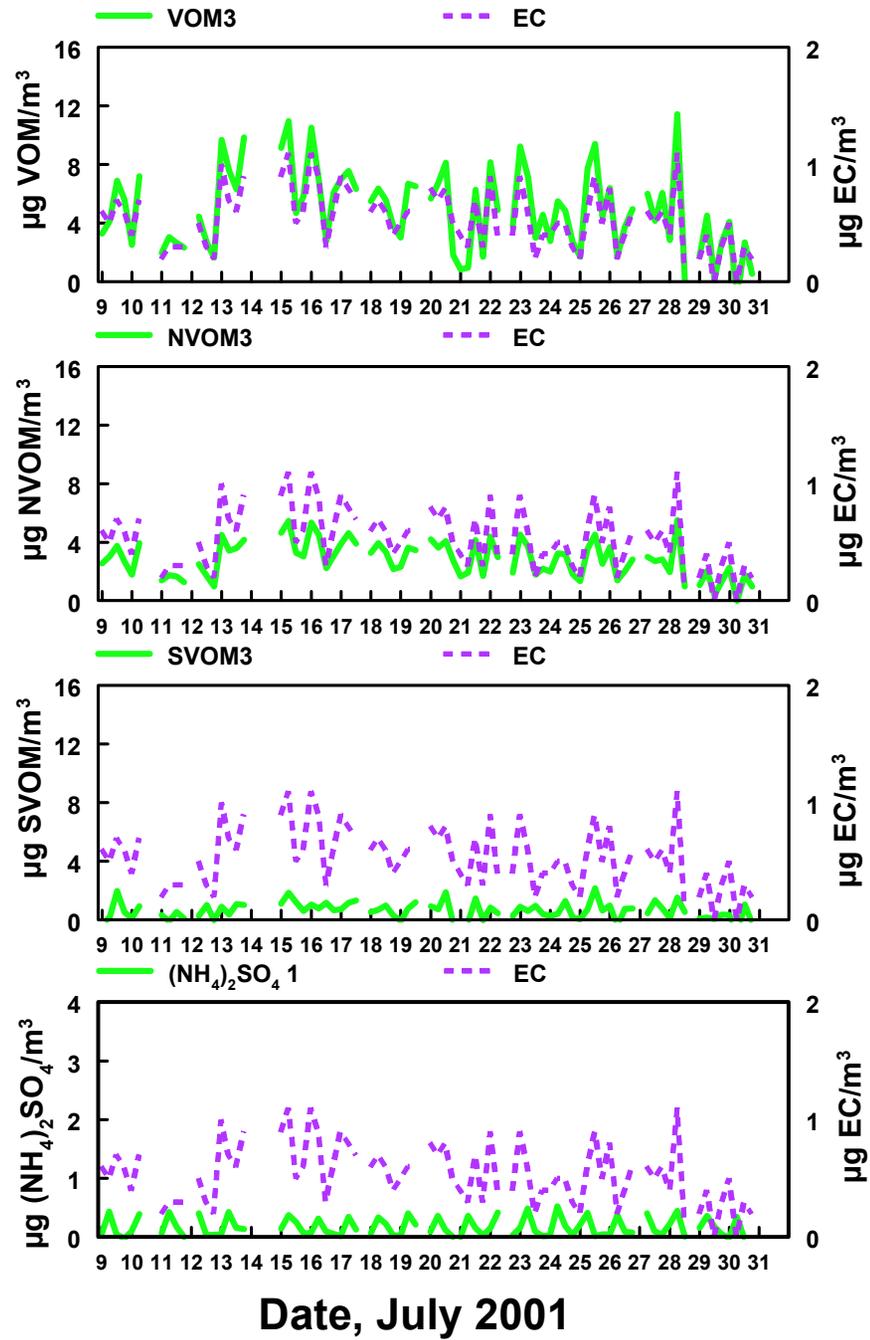
Tracer/Species	Source 1 (Local Sec.)	Source 2 (Mobile gas)	Source 2 (Transport Sec.)	Source 3 (Mobile diesel)
EC/PM _{2.5}	0.009	0.057	-0.008	0.071
NVOM/PM _{2.5}	0.164	1.046	0.039	0.484
SVOM/PM _{2.5}	0.723	0.017	0.056	0.078
NO _x /PM _{2.5}	0.190	2.741	-0.125	0.143
NO ₂ /PM _{2.5}	0.152	1.862	- 0.064	0.223
O ₃ /PM _{2.5}	2.224	-0.483	0.778	3.926
(NH ₄) ₂ SO ₄ /PM _{2.5}	0.103	-0.120	0.912	0.367
Average PM_{2.5}	6.97	3.65	10.29	4.9

Gasoline Mobile Primary Emissions (NETL Site)



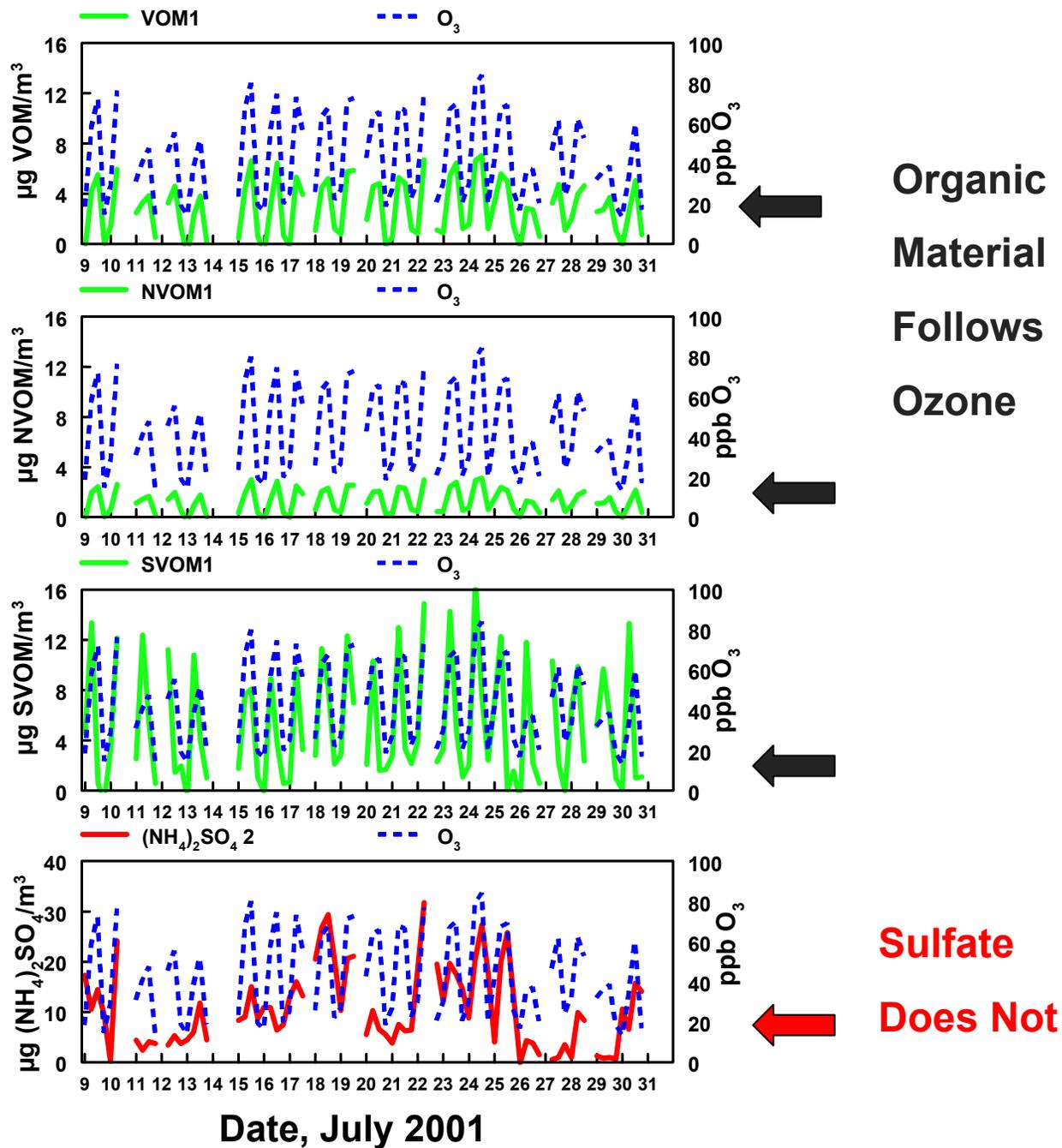
Date, July 2001

Diesel Mobile Primary Emissions (NETL Site)

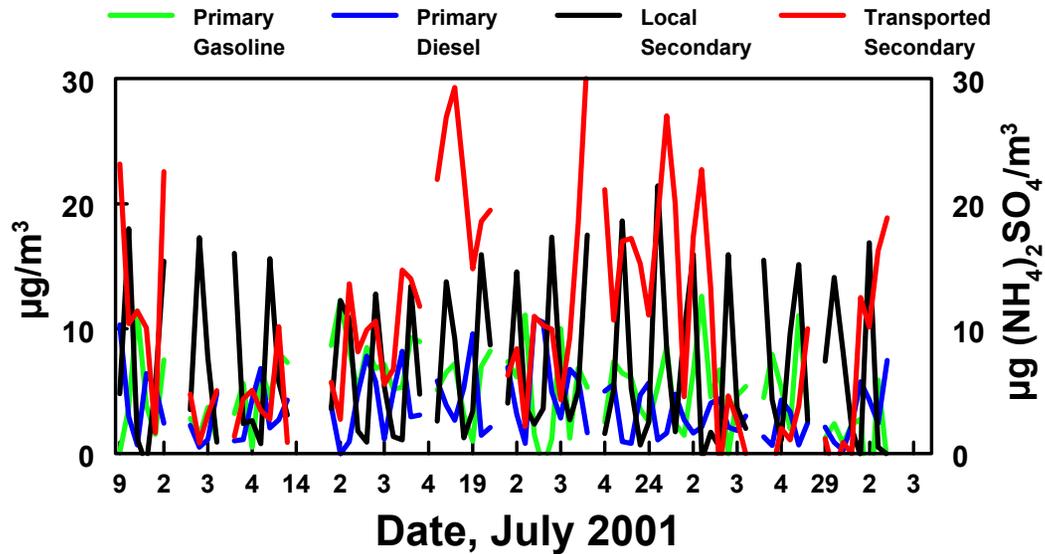
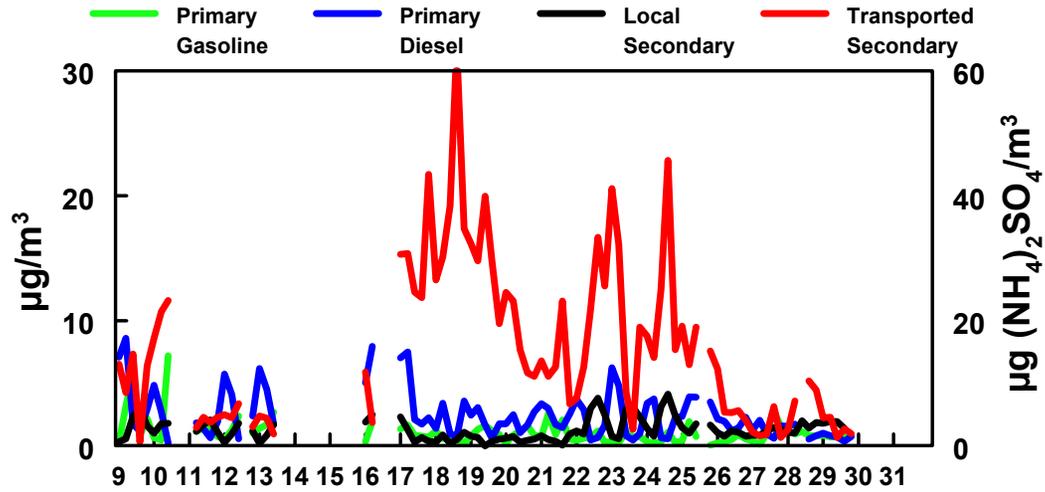


Date, July 2001

Secondary Material (NETL Site)



Unmix 2.3 Results CMU and NETL Sites



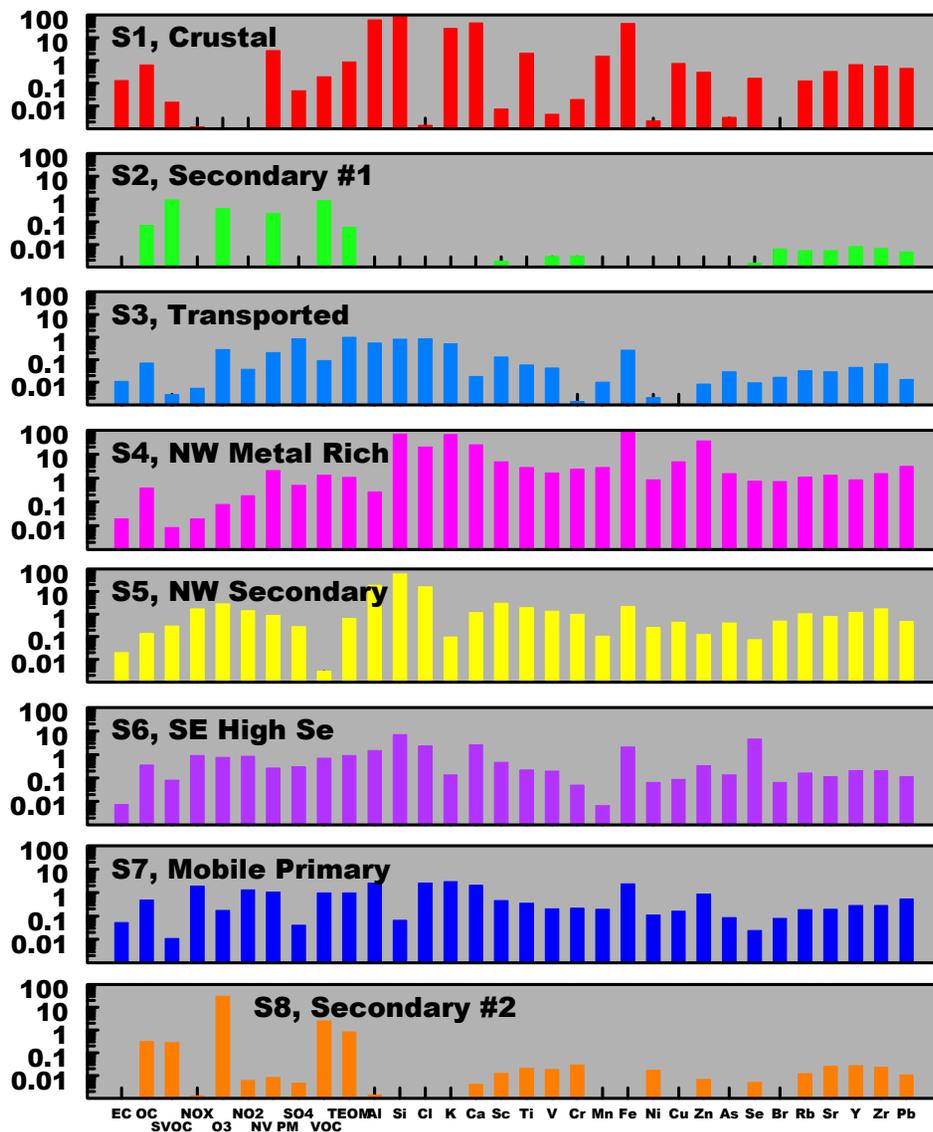
Results

- **Four Sources Identified**
- **Local and Transported origins**
- **Most of Primary - VOM, SVOM and NVOM showed similar diurnal variation (local sources)**
- **Most of Secondary - Ammonium Sulfate (distant sources)**

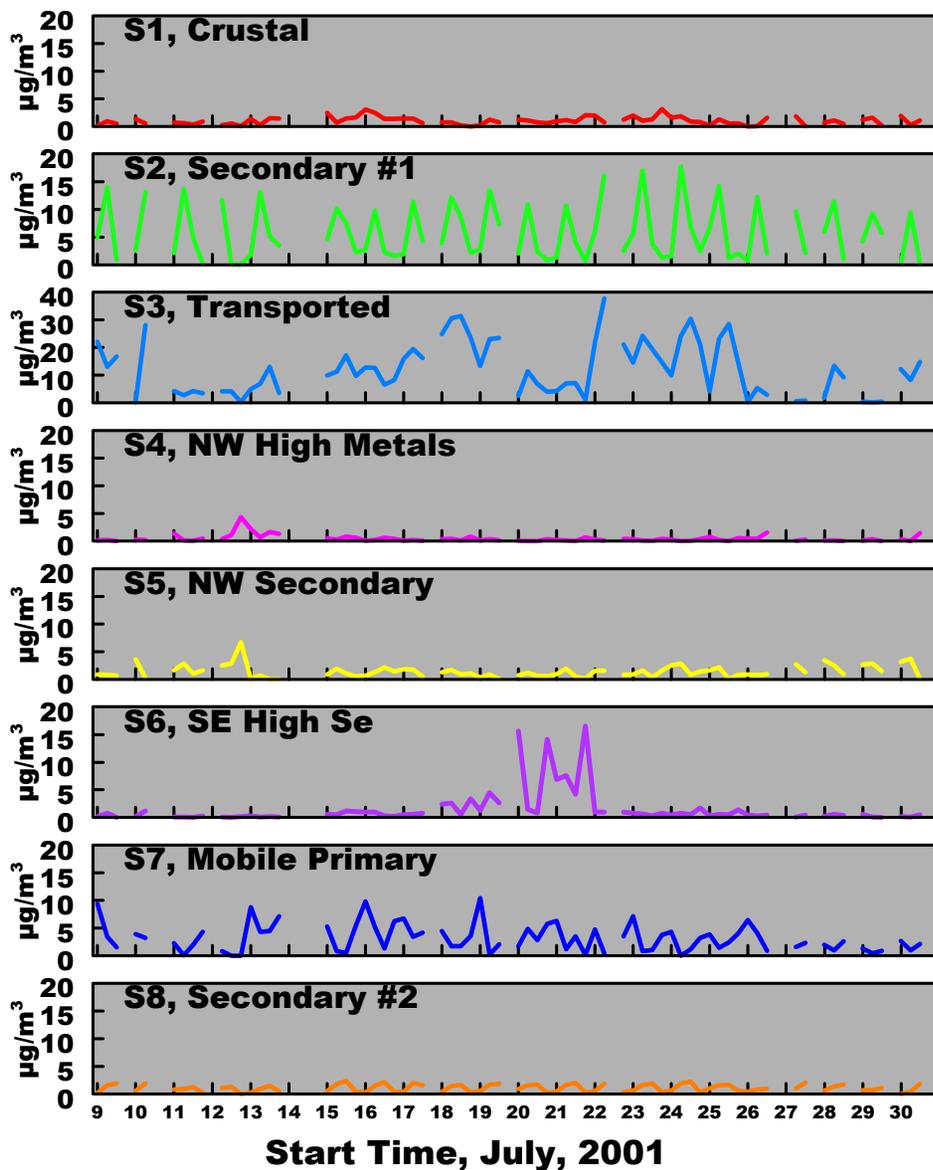
Examine Regional vs. Local Sources

- **PMF2 model**
- **EPA – DOE Summer (July) 2001 Intensive Sampling Period**
- **24 hour filter data for PM fine, carbon, organics, sulfate, nitrate, and metals**
- **Continuous gas data included**

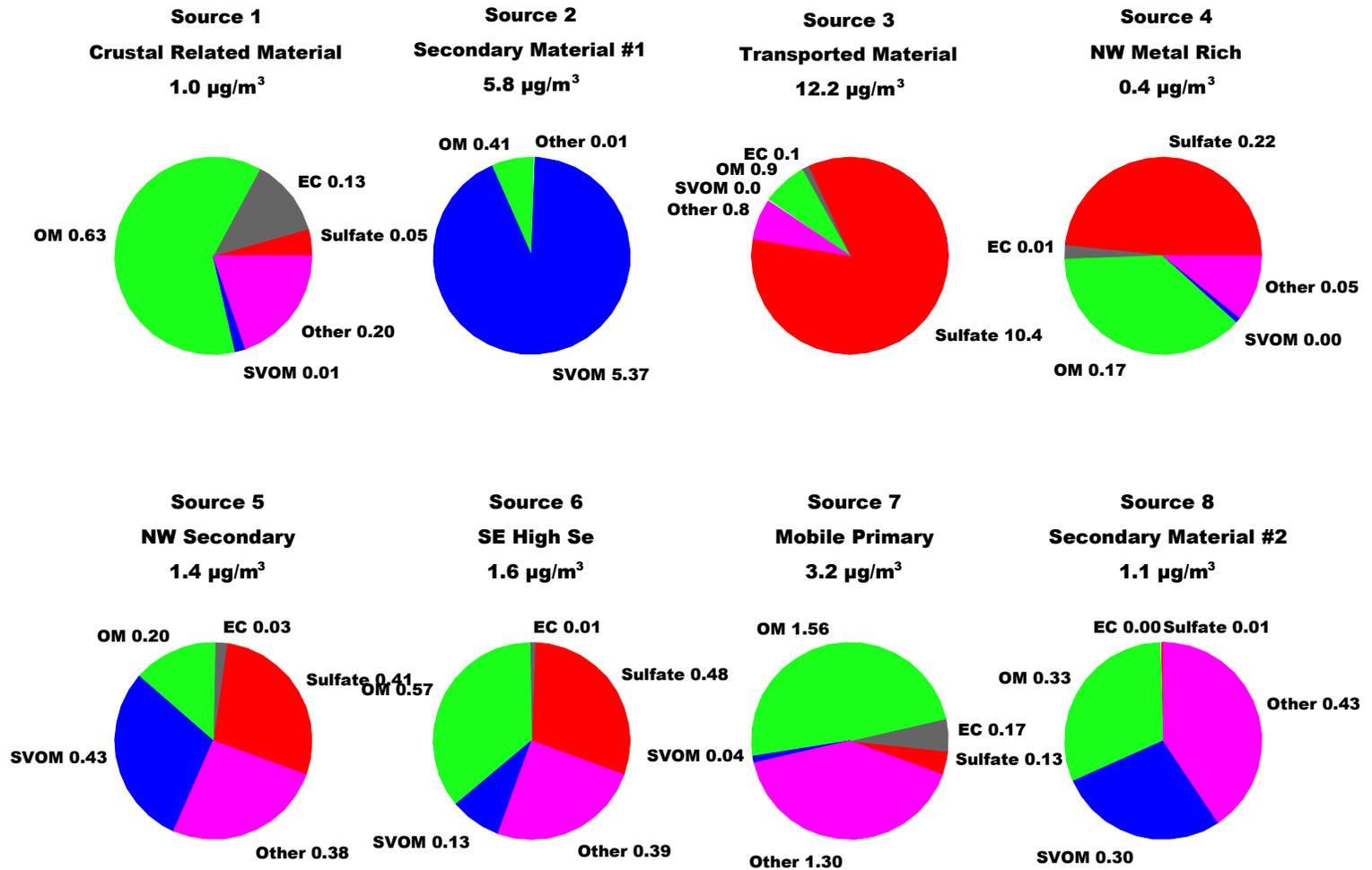
PMF2 Source Profiles – NETL Site



PMF2 Source Variations – NETL Site



PMF2 Results – NETL Site



Results

- **Eight Sources Identified**
- **Local and Transported origins**
- **Most of the PM is Secondary (Ammonium Sulfate) from distant sources**
- **Next greatest is Secondary 1 (SVOC) from local mobile sources**
- **Other minor sources include local and transported crustal, organics, and metals**

Conclusions

- **The models identify particular species' contribution to measured PM**
- **Provide information about source origins**
- **Provide information useful to develop regional air quality strategies**

Future work

- **Include an expanded data set (longer calendar time period) to confirm sources and source origins**
- **Include higher time resolved data to refine source profiles and source origins**

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